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Indoor environmental quality and the prevalence of childhood asthma and rhinitis in Wuhan area of China

ZHANG Ming[1], ZHOU ESheng[2], YE Xin[1], SUN YueXia[3*], SUNDELL Jan[4] & YANG Xu[1*]

[1] *Hubei Key Laboratory of Genetic Regulation and Integrative Biology, College of Life Sciences, Central China Normal University, Wuhan 430079, China;*
[2] *Department of Public Health, University Hospital, Central China Normal University, Wuhan 430079, China;*
[3] *School of Environmental Science and Engineering, Tianjin University, Tianjin 300072, China;*
[4] *Department of Building Science, Tsinghua University, Beijing 100081, China*

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Indoor environmental quality is suspected to be at least part of the cause of the increasing prevalence of childhood asthma and allergy. This study is part of the China, Children, Homes, Health (CCHH) project, which was designed to identify the risk factors indoors that are associated with prevalence of asthma and allergy among children in China. A cross-sectional questionnaire study was carried out in Wuhan in 2011. The questionnaire was a modified (to Chinese building characteristics) version of a questionnaire used first in Sweden. The parents of 2193 children, aged 1–8 years, replied, a response rate of 91.4% (2193/2400). Prevalences of asthma and allergic symptoms were calculated, and a *Chi*-square test and multiple logistic regression were used to identify risk factors. Prevalences of health outcomes are "wheezing last 12 months" 18.5%, "cough at night last 12 months" 15.4%, "doctor-diagnosed asthma" 6.0%, "rhinitis last 12 months" 48.7%, "doctor-diagnosed allergic rhinitis" 17.5%. Factors associated with increased risk for asthma, allergy and related symptoms include living in an urban area, dampness (significant), use of gas for cooking, new dwelling decoration (paint and furniture obtained during pregnancy), keeping pets and breast feeding less than 3 months. Factors associated with reduced risk as installing an exhaust fan in the bathroom. Home environmental factors are significantly associated with the prevalence of childhood asthma and rhinitis in Wuhan. Urbanization and dampness problems at home are significant risk factors for doctor diagnosed asthma and allergic rhinitis among children in Wuhan.

children, asthma, rhinitis, home environment, indoor air quality, Wuhan area

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The International Study on Asthma and Allergies in Childhood (ISAAC), found that from 1992–2004, the prevalence of asthma and allergy increased dramatically among children 6–7 years in 56 countries/regions [1–3]. Genetic factors cannot explain this increase [4]. Since children spend 80%–90% of their time indoors, the indoor environment may be important. In earlier studies with the same design, it has been found that indoor pollution can induce asthma, allergic rhinitis, eczema, sick building syndrome, and other health effects [5–11], and also lead to more airways infections [12]. The results of epidemiological studies in China have also found that the prevalence of childhood asthma and allergic diseases has shown a rapid growth over time, but with location disparities [13,14].

In order to characterize the associations between the home environment and Chinese children's health, a national population-based project has been carried out in ten cities, including Wuhan. The present study is part of this CCHH study (China, Children, Homes, Health). Its main aim was to determine the prevalence of asthma and allergy illness among children in the Wuhan area, and to characterize the environmental risk factors that were associated with these

*Corresponding authors (email: yxiasun@gmail.com; yangxu@mail.ccnu.edu.cn)

diseases.

1 Subjects and methods

1.1 Study subjects

This questionnaire-based epidemiological investigation was carried out from April to May 2011 in the Wuhan area. Questionnaires were distributed to parents of 2400 children 1–8 years old in kindergartens and primary schools. One randomly selected kindergarten and three primary schools were invited to join the study. On-site meetings were arranged among parents, school teachers and investigators to distribute questionnaires. Completed questionnaires were returned to school teachers. This study was approved by the Office of Scientific Research Management of Huazhong Normal University.

1.2 Questionnaire

The questionnaire used ISAAC study questions to determine the prevalence of asthma, allergy and related symptoms, and added Swedish DBH and the Bulgarian ALLHOME study questions [5,11] to ascertain indoor environmental characteristics. The added questions were modified slightly to adapt to Chinese homes. The original Swedish/Bulgarian questionnaire has also been used in Denmark, South Korea, Singapore, and USA [9,15,16].

(i) Questions on children's asthma and allergies.

Questions on asthma and allergies are from ISAAC study [17].

(1) Asthma and related-symptoms:

Has your child ever had difficulty breathing, like wheezing sound?

In the last 12 months, has your child had wheezing or whistling in the chest?

In the last 12 months, has your child had a dry cough at night for more than two weeks?

Has your child been diagnosed with asthma by a doctor?

(2) Allergic rhinitis and related-symptoms:

Has your child had rhinitis ever, apart from a cough associated with a cold or the flu?

In the past 12 months, has your child had a problem with sneezing or a blocked nose when he/she did not have a cold or the flu?

Has your child been diagnosed with hay fever or allergic rhinitis by a doctor?

(ii) Questions on home environment exposure and life style.

(1) Building characteristics: residential location; surrounding environment; house type; house size; building age; house ownership; ventilation and heating system; window type; floor and wall covering; housing renovation before and after child was born. (2) Moisture related problems: visible mold or damp on walls, ceilings and floors; previous or present flooding; condensation on windowpane in winter; damp stains on clothing; perception of odors. (3) Life style related factors: breast feeding; daycare attendance; environmental tobacco smoke (ETS) among family members; pet keeping and pet avoidance; room cleaning and window opening (for ventilation) frequencies; home appliances; use of incense; children's outdoor activities.

1.3 Data analysis

The influence of building characteristics, dampness and life style on diagnosed asthma and allergic rhinitis were analyzed by *Chi*-square tests. Factors which reached significant levels in *Chi*-square test were used in binary logistic regression models with adjustment to gender, age and family allergic history (Model I). Then odds ratios of those factors which showed significant trends in Model I were calculated in multiple logistic regression models (Model II). All statistical analysis was performed with the SPSS 17.

2 Results

2.1 Characteristics of investigated children

Parents of 2193 children responded the questionnaire, giving a response rate of 91.4%. Questionnaires were mostly filled out by mothers (64.6%). Table 1 presents personal characteristics of 2193 children, including their ages, gender, length of being breastfed, and family allergic history.

Table 1 Personal characteristics of investigated children

Personal characteristics	Number (%)
Age	
Less than 5 years old	123 (5.6)
5 years old	105 (4.8)
6 years old	226 (10.3)
7 years old	707 (32.2)
8 years old	1032 (47.1)
Gender	
Male	1156 (52.7)
Female	1037 (47.3)
Breastfeeding period	
Never	229 (10.7)
Less than 1 month	101 (4.7)
1–2 months	111 (5.2)
3–6 months	357 (16.6)
More than 6 months	1348 (62.8)
Family allergic history	
Paternal asthma	54 (2.5)
Paternal allergic rhinitis or eczema	126 (5.7)
Maternal asthma	32 (1.5)
Maternal allergic rhinitis or eczema	126 (5.7)

2.2 Prevalence of asthma and allergies among investigated children

Table 2 gives prevalences of asthma and allergies. The trend with increasing age is a decrease in asthma and rhinitis among children.

2.3 Exposure factors

Associations between building characteristics, dampness, life style and diagnosed asthma and rhinitis among children were analyzed by *Chi*-square tests, as shown in Tables 3–5. Living in an urban area, with gas as cooking fuel were strong risk factors for both diagnosed asthma and rhinitis. Living in an apartment, no exhaust fan in the bathroom were associated with diagnosed rhinitis. Building related moisture problems (dampness), especially visible mold, visible damp and condensation on windowpane in winter, were consistent risk factors for asthma and allergies (Table 4). Among life style factors, breastfeeding less than 3 months, pet keeping and use of incense were associated to a higher prevalence of asthma and rhinitis (Table 5).

2.4 Logistic regression for children's asthma and allergic rhinitis

Factors which had significant influence on health outcomes (Tables 3–5) in crude *Chi*-square test were analyzed in logistic regression models adjusted for gender, age and family allergic history, as shown in Tables 6 and 7. In Model I, an adjusted odds ratio for each variable was calculated separately, while in Model II odds ratios of variables were calculated in multiple logistic regression models.

3 Discussions

This paper presents a basic data set for the association of children's asthma and asthma related symptoms with home environmental factors in Wuhan. As in all cross-sectional studies, the results may be influenced by respondents' bias and unknown sources of confounding. The risk of bias, however, is reduced by the high response rate (91%).

The 48.7% of parents reported that their children had rhinitis in the last 12 months. 31.2% of children had at least one asthmatic symptom, while 50.5% had at least one rhinitis symptom. These prevalences are as great or greater than those reported in traditional high prevalence countries such as the US [16]. This indicates that asthma and allergy problems among Wuhan children should be a public health priority.

Living in an urban area is a strong risk factor for diagnosed asthma and allergic rhinitis. Urbanization has been argued in previous studies to be a cause of the increase in asthma and allergy [18,19]. The causes of the Wuhan increase in asthma in appear to be associated with urbanization and the adoption of a modern "Westernized" lifestyle and their attendant environmental changes.

Among building characteristics, living in an apartment was a risk factor for diagnosed allergic rhinitis compared to living in a single family house. The finding that bigger, owned-by-occupant dwellings with exhaust fan in kitchens had more health problems among occupants was unexpected. After stratification by dwelling types, it was found that those characteristics had a co-linearity with the type of home. After adjustment for dwelling type, the strong associations between ownership and allergic rhinitis disappeared; while smaller houses became a risk factor for rhinitis. New furniture and wall repainting during pregnancy were related to a higher prevalence of asthma and allergic rhinitis, which indicates that early life is a crucial exposure period. Wood as a floor covering, however, was found to be a risk factor compared to cement (Tables 3 and 7). It is suspected that the glues for wood products may emit VOCs (volatile organic compounds), confounding the association between wood flooring and child's asthma and allergy. Further research, especially home inspection, is needed to explore this possibility.

Table 2 Prevalence of asthma and allergic rhinitis symptoms among the investigated children

Symptoms	Age adjusted total, % (*n*)	Stratified by the age of child, % (*n*)					
		< 5 years	5 years	6 years	7 years	8 years	*P* [a)]
Asthma and related-symptoms							
Wheeze in the last 12 months	18.5 (398)	20.7 (25)	20.6 (21)	17.4 (39)	19.2 (133)	17.9 (180)	0.857
Cough at night last 12 months	15.4 (304)	24.6 (30)	21.4 (22)	15.2 (34)	13.9 (96)	12.0 (122)	0.001
Doctor-diagnosed asthma	6.0 (128)	9.9 (12)	7.9 (8)	6.8 (15)	6.2 (43)	4.9 (50)	0.173
Any of the above-mentioned	31.2 (610)	33.6 (40)	30.7 (31)	31.8 (70)	28.7 (196)	27.4 (273)	0.474
Allergic rhinitis and related-symptoms							
Rhinitis last 12 months	48.7 (956)	59.3 (73)	57.7 (60)	43.6 (98)	44.4 (307)	41.1 (418)	0.000
Doctor-diagnosed rhinitis	17.5 (364)	27.0 (33)	30.4 (31)	17.1 (37)	16.1 (112)	14.9 (151)	0.000
Any of the above-mentioned	50.5 (1014)	59.8 (73)	62.7 (64)	44.9 (98)	49.0 (335)	44.4 (445)	0.000

a) *P* value in Pearson *Chi*-square test.

Table 3 Impacts of building characteristics on children's asthma and allergic rhinitis

	Doctor-diagnosed asthma		Doctor-diagnosed allergic rhinitis	
	% (*n*)	*P* [a)]	% (*n*)	*P* [a)]
Dwelling location				
City	7.3 (112)	0.000	19.4 (298)	0.000
Suburb and country	2.6 (16)		10.9 (66)	
Dwelling close to				
highway (yes vs. no)	7.6 (48)	0.018	18.7 (118)	0.144
river/lake (yes vs. no)	7.1 (14)	0.390	24.5 (47)	0.003
business area (yes vs. no)	4.5 (27)	0.112	15.6 (94)	0.310
industrial area (yes vs. no)	4.1 (2)	0.837	12.5 (6)	0.408
House type				
Single and detached house	5.1 (38)	0.154	13.8 (103)	0.000
Apartment	6.7 (76)		20.5 (231)	
House size				
Less than 60 m^2	7.8 (23)		13.6 (40)	
61–100 m^2	5.6 (52)	0.359	14.3 (132)	0.000
More than 100 m^2	5.8 (52)		21.0 (189)	
House age				
Less than 10 years	5.2 (56)	0.208	17.6 (188)	0.536
More than 10 years	6.5 (67)		16.6 (171)	
Ownership				
Yes	6.3 (91)	0.485	18.2 (261)	0.027
No	5.5 (37)		14.3 (94)	
Exhaust fan in kitchen				
Yes	5.9 (122)	1.000	17.6 (360)	0.000
No	5.7 (4)		0 (0)	
Exhaust fan in bathroom				
Yes	6.1 (89)	0.812	12.5 (82)	0.000
No	5.9 (39)		19.2 (279)	
Coal burning				
Yes	5.2 (3)	1.000	10.7 (6)	0.270
No	5.9 (125)		17.1 (358)	
Gas cooking				
Yes	6.9 (87)	0.019	20.7 (259)	0.000
No	4.5 (41)		11.7 (105)	
Floor covering				
Wood board	6.9 (58)		22.0 (183)	
Plywood board	6.4 (30)	0.272	18.4 (86)	0.000
Stone/tiles board	4.9 (22)		11.5 (52)	
Cement	4.5 (17)		10.4 (39)	
Furniture purchase				
Before pregnancy	5.5 (52)		15.6 (146)	
During pregnancy	5.3 (2)	0.998	18.4 (7)	0.312
In 0–1 years old	4.8 (1)		28.6 (6)	
After 1 years old	5.3 (13)		18.4 (45)	
Room repaint				
Before pregnancy	4.6 (8)		18.0 (31)	
During pregnancy	5.9 (1)	0.902	29.4 (5)	0.512
In 0–1 years old	5.9 (1)		29.4 (5)	
After 1 years old	6.4 (12)		20.1 (38)	

a) *P* value in Pearson *Chi*-square test.

Table 4 Impacts of moisture related factors on children's asthma and allergic rhinitis

Exposure factors	Doctor-diagnosed asthma		Doctor-diagnosed allergic rhinitis	
	% (*n*)	*P* [a)]	% (*n*)	*P* [a)]
Visible mold				
Yes	12.2 (17)	0.001	23.9 (33)	0.024
No	5.4 (102)		16.4 (310)	
Visible damp				
Yes	5.2 (93)	0.003	21.3 (49)	0.052
No	10.0 (23)		16.2 (290)	
Flooding				
Yes	6.7 (15)	0.563	22.0 (50)	0.033
No	5.7 (101)		16.4 (287)	
Condensation				
Yes, ⩽5 cm	5.2 (66)	0.004	15.3 (194)	0.000
Yes, >5 cm	9.5 (31)		24.3 (79)	
Damp stains on clothing				
No	5.4 (69)	0.134	15.8 (200)	0.123
Yes	6.5 (55)		18.4 (156)	
Stuffy smell often				
No	5.3 (62)	0.069	15.9 (184)	0.186
Yes	7.3 (61)		18.2 (151)	
Moldy/earthy smell often				
No	5.9 (94)	0.586	16.7 (266)	0.762
Yes	6.6 (23)		16.0 (55)	

a) *P* value in Pearson *Chi*-square test.

Table 5 Impacts of life style related factors on children's asthma and allergic rhinitis

Exposure factors	Doctor-diagnosed asthma		Doctor-diagnosed allergic rhinitis	
	% (*n*)	*P* [a)]	% (*n*)	*P* [a)]
Breast feeding				
Less than 3 months	7.0 (39)	0.269	20.9 (117)	0.004
More than 3 months	5.6 (75)		15.4 (204)	
ETS				
Yes	5.5 (68)	0.278	16.0 (196)	0.145
No	6.6 (59)		18.4 (163)	
Pets keeping				
Yes	6.1 (25)	0.927	21.6 (88)	0.006
No	6.0 (103)		15.9 (272)	
Use of incense				
Often	14.3 (9)	0.004	19.0 (12)	0.657
Sometimes/never	5.7 (114)		16.9 (338)	
Home cockroach				
Always/often	10.1 (17)	0.017	19.3 (32)	0.373
Sometimes/never	5.6 (100)		16.6 (297)	
Home mice and/or rats				
Always/often	8.4 (7)	0276	16.9 (14)	0.990
Sometimes/never	5.6 (101)		16.8 (303)	
Home mosquitoes and flies				
Always/often	6.4 (34)	0.658	17.8 (95)	0.566
Sometimes/never	5.8 (92)		16.7 (262)	
Put bed sheets under sunshine				
Often	5.5 (91)	0.096	17.1 (281)	0.825
Sometimes/never	7.5 (36)		16.6 (80)	
Cleaning frequency				
Less than once per week	10.3 (11)	0.058	19.2 (20)	0.553
More than once per week	5.8 (117)		17.0 (341)	

a) *P* value in Pearson *Chi*-square test.

Table 6 Risk factors on children's diagnosed asthma

Exposure factors	Doctor-diagnosed Asthma (AOR (95% CI))	
	Model I*	Model II**
Dwelling location urban (ref: suburban/country)	2.35 (1.36, 4.07)	2.91 (1.55, 5.45)
Dwelling close to highway (ref: no)	1.31 (0.88, 1.95)	
Gas cooking (ref: no)	1.44 (0.97, 2.14)	
Visible mold (ref: no)	2.09 (1.17, 3.75)	1.51 (0.72, 3.17)
Visible damp (ref: no)	2.00 (1.21, 3.29)	1.90 (1.01, 3.56)
Condensation > 5 cm (ref: <5 cm)	1.50 (0.94,2.40)	
Use of incense often (ref: sometimes/never)	2.24 (1.05, 4.78)	2.04 (0.87, 4.77)
Homeof cockroach often (ref: sometimes/never)	1.40 (0.79, 2.47)	

* Model I: Odds ratios of each variable calculated separately with adjustment for gender, age and family allergic history; ** Model II: Odds ratios of dwellings location, visible mold, visible damp and use of incense in multiple logistic regression models adjusted for gender, age and family allergic history.

Table 7 Risk factors on children's diagnosed allergic rhinitis

Exposure factors		Doctor-diagnosed allergic rhinitis (AOR (95% CI))	
		Model I *	Model II **
Dwelling location urban (ref: suburban/country)		1.73 (1.28, 2.35)	1.51 (0.85, 2.69)
Dwelling close to river/lake (ref: no)		1.55 (1.06, 2.25)	1.13 (0.63, 2.01)
House type: apartment (ref: single family house)		1.53 (1.16, 2.00)	1.57 (0.99, 2.49)
House size (m^2)	More than 100	1.00	1.00
	Less than 60	0.60 (0.40, 0.89)	0.97 (0.43, 2.17)
	61–100	0.67 (0.51, 0.86)	1.09 (0.48, 2.48)
Owner of dwelling (ref: rent dwelling)		1.40 (1.06, 1.87)	1.21 (0.71, 2.05)
No exhaust fan in bathroom (ref: fan in room)		1.57 (1.18, 2.08)	1.33 (0.76, 2.32)
Gas cooking (ref: no)		1.84 (1.42, 2.39)	1.35 (0.83, 2.19)
Floor covering	Cement	1.00	
	Wood board	2.31 (1.56, 3.41)	1.37 (0.74,2.55)
	Plywood board	1.48 (0.95, 2.28)	
	Stone/tiles board	1.05 (0.66, 1.57)	
Visible mold (ref: no)		1.39 (0.89, 2.18)	
Flooding (ref: no)		1.19 (0.82, 1.71)	
Condensation (ref: <5 cm)		1.53 (1.12, 2.11)	1.42 (1.01, 2.00)
Breastfeeding > 3 months (ref: < 3 months)		1.24 (0.94, 1.63)	
ETS (ref: no)		0.99 (0.80, 1.22)	
Pets keeping (ref: no)		1.60 (1.20, 2.13)	1.67 (0.99, 2.81)

* Model I: Odds ratios of each variable in binary logistic regression models with adjustment to gender, age and family allergic history; ** Model II: Calculation of adjusted odds ratios in multiple logistic regression models of variables which reached significant level in model I.

Dampness problems in the Wuhan area are serious and signs of dampness, especially the index of visible dampness and condensation on windowpane in winter, were strong and significant risk factors for asthma and allergy. This finding is consistent with previous international parallel studies carried out in regions with different climates [5,11, 12]. Condensation on window panes in winter is a proxy for poor ventilation [20]. Humid air condenses on cold surfaces such as walls and ceilings when extra moisture cannot be removed from the room, perhaps due to a lower air change rate. We found that behaviors or life styles that reduce dampness problems, for example installing exhaust fan in bathrooms, were associated with less asthma and allergic rhinitis among children in Wuhan. The association of air change rate in Wuhan dwellings with health outcomes of children shall be studied in the next step.

Among life style factors, breast feeding for less than 3 months, pet keeping at home and use of incense were related to a higher prevalence of asthma and allergic rhinitis. These findings are consistent with previous global children and home studies in Europe, America and Asia [21,22].

In conclusion, asthma in Wuhan children poses challenges for planners, architects, health services, and researchers to respond to the growing burden of asthma disability,

especially among urban populations. Urbanization, and dampness problems are strong risk factors for diagnosed asthma and allergic rhinitis among children in Wuhan area.

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